



## **Section 2**

### **Mission Overview**



### Outline



- Mission/Science Summary
- Spacecraft and Instrument Overview
- Ground System Overview
- Status/Schedule



### GLAST: DOE and NASA Partnership



# Department of Energy Office of Science

Understand the nature of matter at the most fundamental level and to explore the evolution and fate of the universe through fundamental interactions of energy, matter, time and space.

# NASA - Office of Space Science

Chart the evolution of the universe, from origins to destiny

- 1. Understand the structure of the universe
- 2. Explore the ultimate limits of gravity and and energy in the universe
- 3. Learn how galaxies, stars and planets form, interact and evolve





**Astronomy/astrophysics** 

# Gamma ray Large Area Space Telescope (GLAST)

An astro-particle physics partnership to explore the highenergy universe



### **GLAST Science**



- GLAST is a high-energy gamma-ray observatory for observing celestial sources in the energy band extending from 20 MeV to 300 GeV with complementary coverage between 10 keV and 25 MeV for gamma-ray bursts. GLAST will:
  - Identify/study nature's high-energy particle accelerators through observations of active galactic nuclei, pulsars, stellar-mass black holes, supernova remnants, gamma-ray Bursts, solar and stellar flares, and the diffuse galactic and extragalactic high-energy radiation.
  - Use these sources to probe important physical parameters of the galaxy and the universe such as: intensity of infrared radiation fields, magnetic fields strengths in cosmic particle accelerators, and diffuse gamma-ray fluxes from the Milky Way and nearby galaxies, and the diffuse extragalactic gamma-ray background radiation.
  - Use high-energy gamma-rays to search for fundamentally new phenomena: particle dark matter, quantum gravity, and evaporating black holes.



### **GLAST Science**



### GLAST will have a very broad menu that includes:

- Systems with supermassive black holes
- Gamma-ray bursts (GRBs)
- Pulsars
- Solar physics
- Origin of Cosmic Rays
- Probing the era of galaxy formation
- Discovery! Particle Dark Matter? Other relics from the Big Bang? Testing Lorentz invariance. New source classes.

Huge increment in capabilities.

GLAST draws the interest of both the the High Energy Particle Physics and High Energy Astrophysics communities.



### GRB Science Repoint Scenarios



- During all-sky scanning operations, detection of a sufficiently bright burst will cause the observatory to interrupt the scanning operation autonomously and to remain pointed at the burst region during the non-occulted viewing time for a period of 5 hours (adjustable) – two cases:
- Burst occurs within LAT Field of View
  - The observatory will slew to keep the burst direction within 30 degrees (adjustable) of the Z axis during the non-occulted viewing period (neglecting SAA effects). Such events are likely to occur a few times per month.

#### Burst occurs outside LAT Field of View

- If the burst is exceptionally bright, the observatory will slew to bring the burst direction within 30 degrees (adjustable) of the Z axis during the non-occulted viewing period (neglecting SAA effects)
- Such events are likely to occur a few times per year.



## **GLAST Mission Summary**



▶GLAST: Gamma-Ray Large Area Space Telescope

**▶**Objective:

Larger field of view (FOV), higher sensitivity, and broader energy detection range than any
previously flown gamma-ray mission. Affords scientists the unprecedented opportunity to
sample the history of the universe, a variety of high energy astrophysical phenomena, and
many of the little understood features of the sky

▶ Launch Date: September 2006

▶ Mission Duration: 5 yrs (10 yr Goal)

▶Minimum Success: 2 years

▶Orbit: 565 km Circular, 28.5° Inclination

▶ Launch Vehicle: Delta 2920H-10

▶ Launch Site: CCAS (Eastern Range (ER))

▶GS Sites: X- and S-band to Malindi, Kenya (6.1m) and USN (11m)

▶ TDRSS (SN): S-Band Single Access and Multiple Access (scheduled);

Demand Access Service (near continuous access)

Large Area
Telescope (LAT)

GLAST Burst Monitor (GBM)

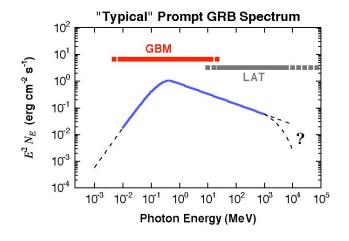


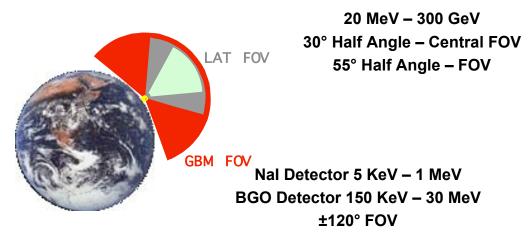
## **Ops Concept**



### Key Features:

- First year all-sky survey scanning operations
- Pointed observations to any celestial target after first year
- Gamma Ray Burst alert messages with low latency to ground
- Accommodate uploadable Targets of Opportunity (TOOs)
- Autonomous repointing to Gamma Ray Bursts





GLAST Survey: ~300 sources (2 days)



### **GLAST Telecom Architecture**



GLAST Orbit (450 - 575 km) Point 'Anywhere, Anytime' Orientation

#### Malindi & USN:

- X-Band Science Data 20Mbps
- S-Band Command and Uplink Data 2kbps
- S-Band Downlink Telemetry 2.5Mbps (w/32 kbps RT HK)

#### **TDRSS SN Links:**

- SA Forward 4kbps
- MA Forward 250bps
- SA Return 1,2,4,8kbps

**GEO Orbit** 

• MA Return 1kbps

#### White Sands, N.M.:

- STDN SN CMD and TM
- Demand Access Service



## Spacecraft Subsystem Design



#### **STRUCTURE**

**Aluminum Primary Structure Titanium LAT Support Flexures Externally Mounted Components** Clear Instrument FOVs

COMMAND & DATA HANDLING cPCI Architecture-RAD750 CPU 96 Gbit Solid State Recorder 66 Mbps Peak LAT Data Transfer 12 Mbps Peak GBM Data Transfer

#### **GUIDANCE, NAVIGATION & CONTROL**

2 of 3 Active Star Trackers **High Precision IRU** Goodrich B-Wheels 3-Axis Stabilized **Zero Momentum Biased** 10 arcsec Attitude Knowledge 2° Attitude Control

#### **ELECTRICAL POWER**

2-Single Axis GaAs Solar Arrays Provides >1700 Watts (OAP) EOL 1 - 125 Amp-Hour NiH<sub>2</sub> Battery Unregulated 28V +7/-6 V Regulated 28V ±1 V LAT Power

#### SOFTWARE

**Fault Detection and Management** Supports Science Operations, Observatory Safe Mode, ISM Manages Playback Of SSR **Provides 1553 Bus Control Management Support SC Nominal Operations Provide Re-Entry Capability** 



12 - 22N Redundant Thrusters

THERMAL CONTROL **Passive with Heaters CCHP Heat Pipe** 

#### COMMUNICATIONS

S-Band to GN:

2 Kbps Uplink

2.5 Mbps Downlink

Omni Antennas

TDRSS - SA:

4 Kbps CMD/1 Kbps TLM

X-Band:

20 Mbps Science Data Gimbaled X-Band Antenna

#### **HERITAGE**

- Based on SA-200HP, Option 1 from RSDO Catalog Bus
- Design Enhancements From Coriolis / SWIFT Heritage

2 - 10 \* Modified from Spectrum Astro SC PDR



## Mission Modes



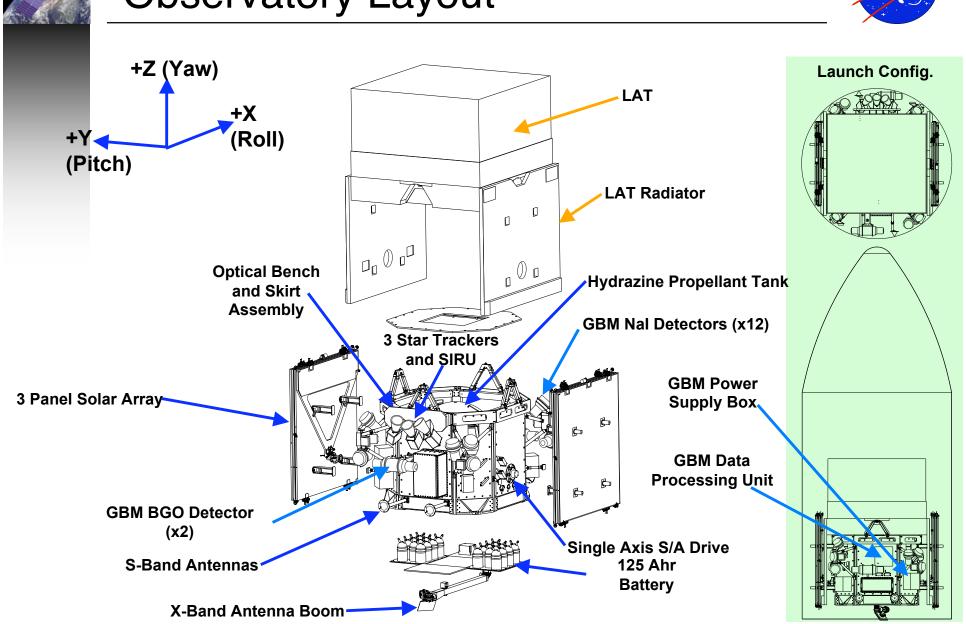
Mission Mode	Description	
Launch	Configuration During Launch and Ascent. Essential Bus Powered ON. Capability for Survival Heaters to Be Enabled.	
Early Orbit	Deployment and Activation After Separation. Rate Nulling, Deploy Arrays, Acquire Sun, Maneuver to Sun Point and Wait for MOC.	
Standby/Engineering	Used for Checkout, Instrument Cal, SW Uploads, and Safemode Transitions.	
Sky Survey	Science Mode With Zenith Pointing and Yaw Steering. Includes Roll Rocking.	
Pointed and Repointed	Science Mode to Point Anywhere, Anytime, for Any Duration With Autonomous Earth Avoidance. Repointed Supports Interrupts for TOOs or LAT Repoint Requests.	
Safemode	Inertially Fixed, Known State for Observatory Anomaly Conditions. Nominal Safemode is OSM (Observatory Safemode). Also Have ISM (Independent Safemode for Generic SW Errors)	
Re-Entry	Used for Burn and Coast Periods of Controlled Re-Entry.	

\* From Spectrum Astro SC PDR



## **Observatory Layout**







### **GLAST LAT Collaboration**



#### **United States**

- California State University at Sonoma
- University of California at Santa Cruz Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Stanford University Hanson Experimental Physics Laboratory
- Stanford University Stanford Linear Accelerator Center
- ► Texas A&M University Kingsville
- University of Washington
- Washington University, St. Louis

#### **France**

- Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules
- Commissariat à l'Energie Atomique / Direction des Sciences de la Matière/ Département d'Astrophysique, de physique des Particules, de physique Nucléaire et de l'Instrumentation Associée

#### <u>Italy</u>

- Istituto Nazionale di Fisica Nucleare
- Istituto di Fisica Cosmica, CNR (Milan)

#### Japanese GLAST Collaboration

- Hiroshima University
- Institute for Space and Astronautical Science
- RIKEN

#### Swedish GLAST Collaboration

- Royal Institute of Technology (KTH)
- Stockholm University

### PI: Peter Michelson (Stanford & SLAC)

124 Members (including 60 Affiliated Scientists, plus 16 Postdoctoral Students, and 26 Graduate Students)

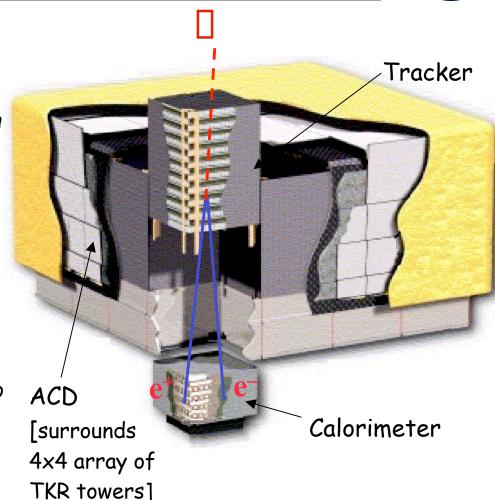
LAT Project is a partnership between NASA and DOE, with international contributions from France, Italy, Japan and Sweden. Managed at Stanford Linear Accelerator Center (SLAC).



### Overview of LAT Instrument



- Precision Si-strip Tracker (TKR) 18 XY tracking planes. Single-sided silicon strip detectors (228 ☐m pitch) Measure the photon direction; gamma ID.
- ► Hodoscopic Csl Calorimeter(CAL)
  Array of 1536 Csl(Tl) crystals in 8
  layers. Measure the photon energy;
  image the shower.
- ► <u>Segmented Anticoincidence Detector</u>
  (ACD) 89 plastic scintillator tiles.
  Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.
- ► <u>Electronics System</u> Includes flexible, robust hardware trigger and software filters.



Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.



### **GBM Collaboration**





**National Space Science & Technology Center** 



University of Alabama in Huntsville

Michael Briggs
William Paciesas
Robert Preece

Marshall Space Flight Center

NASA Marshall Space Flight Center

Charles Meegan (PI) Gerald Fishman Chryssa Kouveliotou Max-Planck-

Max-Planck-Institut für extraterrestrische Physik

Giselher Lichti (Co-PI)
Andreas von Keinlin
Volker Schönfelder
Roland Diehl

On-board processing, flight software, systems engineering, analysis software, and management

Detectors, power supplies, calibration, and analysis software



### Overview of GBM Instrument

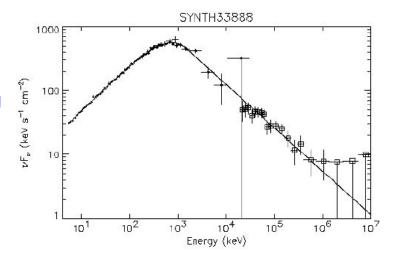


 Provides spectra for bursts from 10 keV to 30 MeV, connecting frontier LAT high-energy measurements with more familiar energy domain;

Simulated GBM and LAT response to timeintegrated flux from bright GRB 940217

Spectral model parameters from CGRO wide-band fit

1 NaI (14°) and 1 BGO (30°)



- Provides wide sky coverage (8 sr) -- enables autonomous repoint requests for exceptionally bright bursts that occur outside LAT FOV for high-energy afterglow studies (an important question from EGRET);
- Provides burst alerts to the ground.



### **GBM Detectors**



Mass: 97 kg

Instrument Size: See diagrams (at right)

Science FOV: Targets 0-120° from +Z; >25° apart;

FOV must be covered by  $\geq$  3 Nal sensors within 80°, with Ps >95%; one BGO sensor visible with Ps

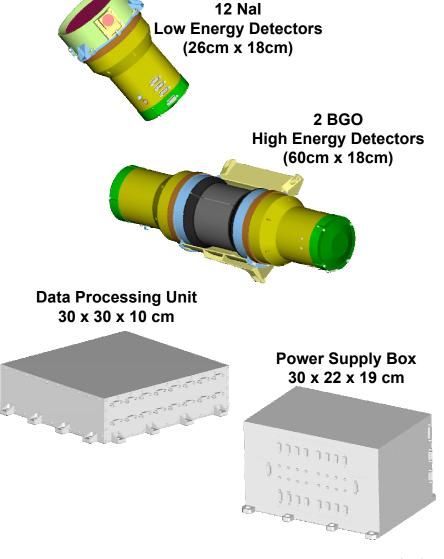
>95%.

Mounting: S/C supported.

#### **Key GBM Accommodation Requirements:**

12 Sodium Iodide (NaI) and 2 Bismuth Germanate (BGO) detectors distributed around spacecraft bus

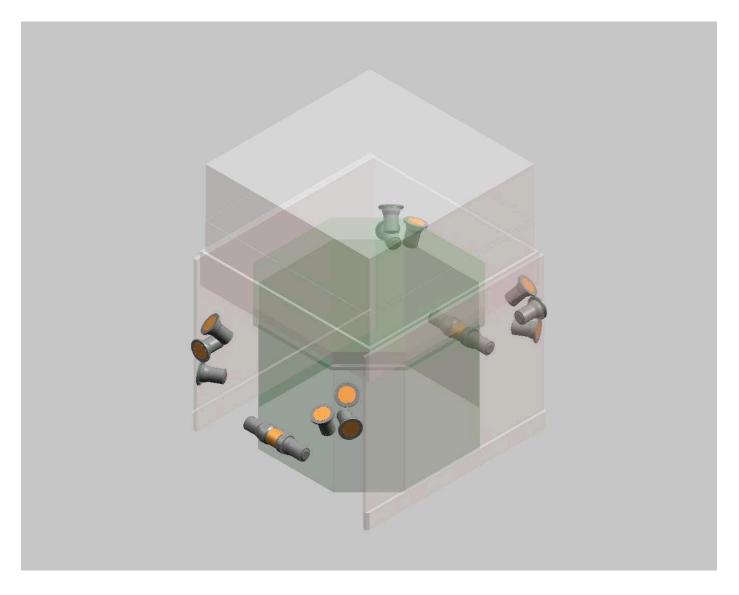
Data Processing Unit and GBM Power Box located on spacecraft.





## **GBM** Detector Placement

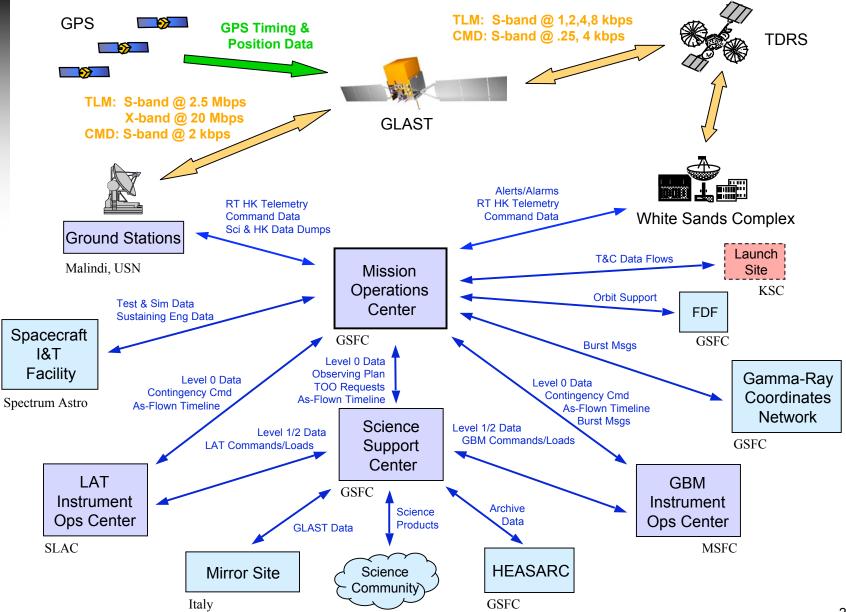






## **Ground System Architecture**









- Ground Station Network (Malindi & USN)
  - Provide primary space-to-ground communications support
    - Simultaneous X-band and S-band
  - Performs RS-decoding, reports statistics to MOC, sorts data by virtual channel and time stamps data at the frame level
  - Forwards real-time data to MOC; records dump data and forwards to MOC
  - Provides approximately 20 contact opportunities per day (using primary USN sites in Hawaii and Australia) need approximately 6 per day
- Space Network (TDRS, WSC, DAS, SWSI)
  - Provides communications support for Burst Alert Messages, spacecraft alarm messages, and Housekeeping data
  - Provides continuous MA return service via the Demand Access Service (DAS)
  - Provides schedulable MA forward, SA forward and return also available





### Mission Operations Center (MOC)

- Provides real-time command & control, telemetry processing, and data monitoring and analysis
- Provides 24x7 operations support with 8x5 operations staffing
- Provides mission planning, TOO handling, Level 0 data processing
- Serves as single point of commanding for the ground system
- Generates As-Flown Timeline to document what observatory actually accomplished (e.g., reflects autonomous repointing)
- Design based on Swift MOC architecture (e.g., ITOS)

### Flight Dynamics Facility (FDF)

- Generates definitive orbit products based on Two-Line Elements (TLE's) from NORAD and sends to MOC
- Also using Differenced One-Way Doppler (DOWD) from TDRSS,
   which would go to FDF for use in orbit product generation





### GLAST Science Support Center (GSSC)

- Supports the Guest Investigator program
- Reviews commands and memory loads from the IOC's for their impact on the observing timeline (science-level constraint checking)
- Provides the MOC with an observing timeline based on accepted
   Guest Investigator proposals, IOC inputs, and science requirements
- Generates Target of Opportunity orders approved by the Project Scientist and forwards to the MOC
- Ingests data from the MOC (level 0) and IOC's (Level 1/2) for distribution to the science community and mission archives at the HEASARC
- Distributes analysis tools to the science community

#### HEASARC

- Provides long-term permanent archive for GLAST
- Receives data products from SSC





### LAT Instrument Operations Center (IOC)

- Performs higher level data processing (Level 1 & 2) using Level 0 data provided by MOC, and provides Level 1 data products to the GSSC
- Archives and distributes science data products (for LAT collaborations)
- Supports instrument calibration activities
- Performs instrument activity planning, trending & performance analysis and anomaly investigation

#### GBM IOC

- Performs higher level data processing (Level 1 & 2) using Level 0 data provided by MOC, and provides Level 1 data products to the GSSC
- Archives and distributes science data products (for GBM collaborations)
- Supports instrument calibration activities
- Performs instrument activity planning, trending & performance analysis and anomaly investigation
- Provides a Burst Alert Processor (BAP) to the MOC that performs additional processing of Burst Alerts to improve burst location information to the GCN
  - BAP serves as GCN front-end for MOC for all Burst Alerts





### Gamma-Ray Coordinates Network (GCN)

- Receives Burst Alerts (GCN Notices) from the Burst Alert Processor resident in the MOC and the IOC's
- For real-time Burst Alerts from BAP, forwards immediately to the science community for rapid follow-up observations
- Can later receive additional Burst location information from the BAP and IOC's that is forwarded to the science community

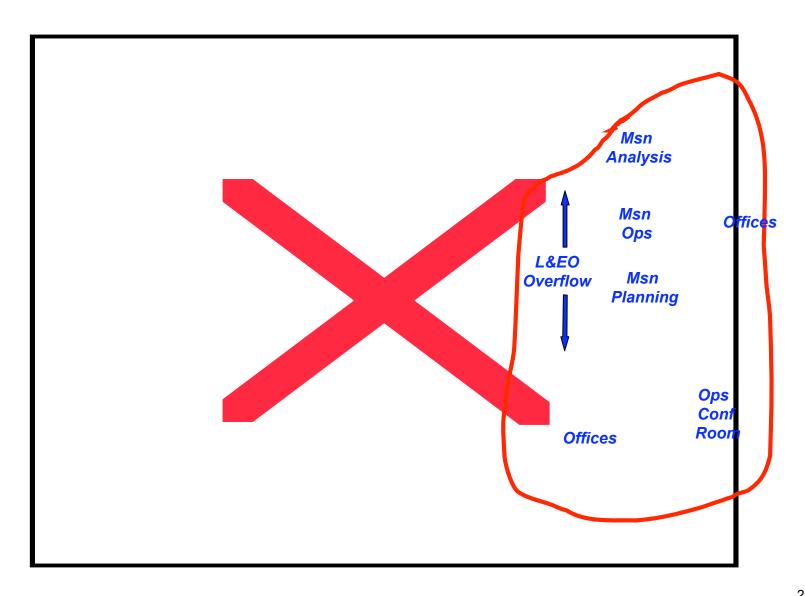
### Spacecraft I&T Facility

- Provides access to spacecraft and instruments during pre-launch testing and operations simulations activities
- Provides flight software maintenance and general sustaining engineering support (option in Spectrum contract)
- Hosts copies of the MOC system, and the FOT



# MOC Facility (preliminary)

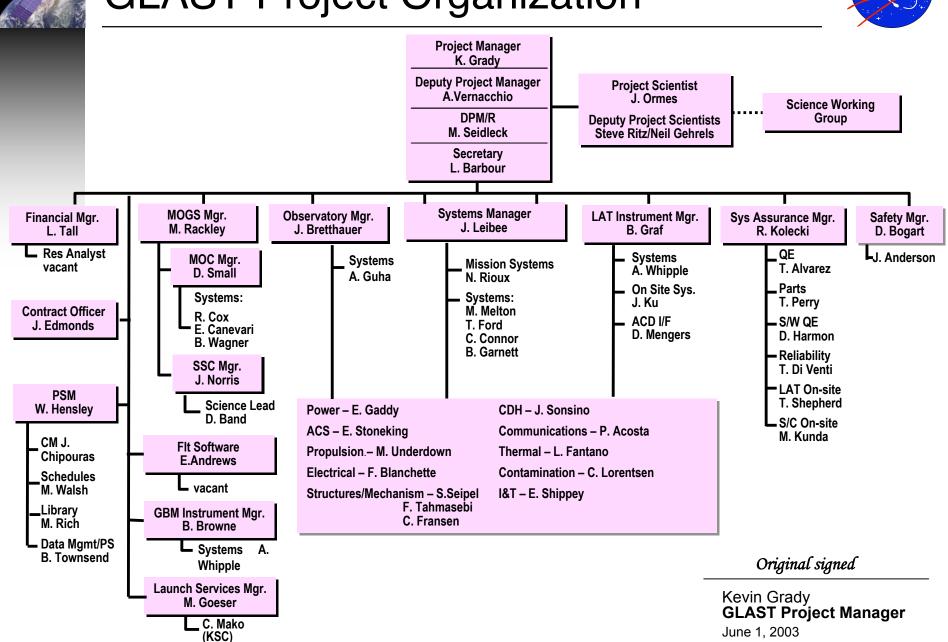






## **GLAST Project Organization**







## **Team Members**

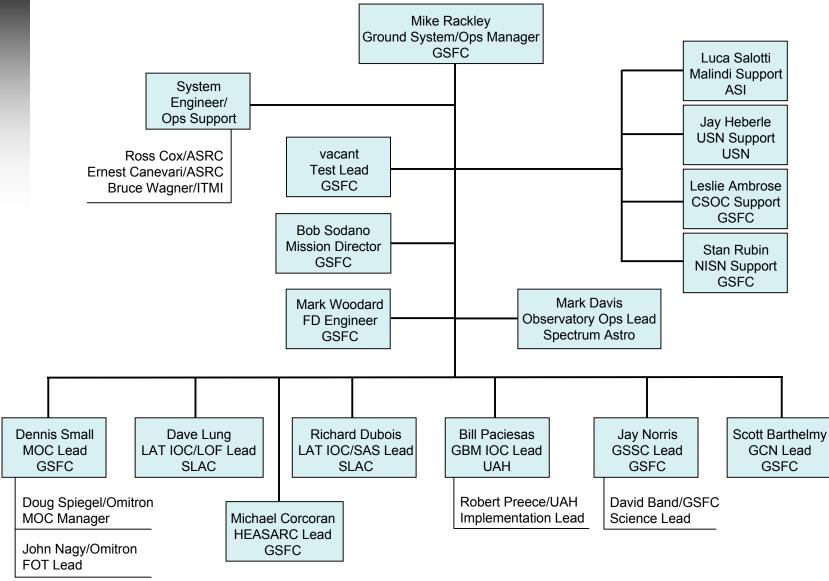


Element	Lead	Location
Malindi Ground Station	Italian Space Agency (ASI)	Kenya, Africa
Commercial Ground Station	USN	Hawaii (South Point), Australia
SN	Code 450	GSFC
MOC/Flight Operations	Goldbelt Orca/Omitron	GSFC
LAT IOC	Stanford Linear Accelerator Center (SLAC)	Stanford, CA
GBM IOC	Marshall Space Flight Center/ University of Alabama	MSFC
GSSC	Code 660	GSFC
GCN	Code 660	GSFC
HEASARC	Code 660	GSFC
FDF	Code 450/Code 595	GSFC
Spacecraft (dev/I&T/ops)	Spectrum Astro	Gilbert, AZ



## Ground System/Ops Organization





Version: 7/9/03 2 - 28



### **Project Status**



- LAT instrument completed detailed design (CDR May '03)
- GBM instrument completed preliminary design (PDR Feb '02 )
  - CDR scheduled for January 2004
  - GBM IOC PDR completed May 2003
- S/C contract awarded to Spectrum Astro Inc. August 2002.
  - SRR November 2002
  - PDR May 2003
  - CDR scheduled for February 2004
- Project conducted Mission PDR June 2003
- Working to establish sole source 8a contract with Gold Belt Orca/Omitron for MOC implementation and flight operations
  - Maximizes benefit of using Swift heritage (same contractor)
  - RFP issued and expect contract award by end August 2003



## Ground System/Ops Schedule



